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THE ENERGY BUDGET AT THE EARTH'S SURFACE: AIR FLOW AND TURBULENCE CHARACTERISTICS IN A JAPANESE LARCH PLANTATION

Contribution by:

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INTERIM REPORT

E. R. Lemon - Investigations Leader

JUNE 1967

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UNITED STATES ARMY ELECTRONICS COMMAND

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Microclimate Investigations, SWCRD-ARS-U. S. Department of Agriculture
Ithaca, New York

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THE ENERGY BUDGET AT THE EARTH'S SURFACE: AIR FLOW AND TURBULENCE CHARACTERISTICS IN A JAPANESE LARCH PLANTATION

INTERIM REPORT

Cross Service Order 2-67

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Prepared by

L. H. Allen, Jr.

Research Report No. 395

of

Northeast Branch
Soil and Water Conservation Research Division
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In Cooperation With

N. Y. State College of Agriculture
Cornell University
Ithaca, New York

For

U. S. Army Electronics Command
Atmospheric Sciences Laboratory, Research Division
Fort Huachuca, Arizona

ABSTRACT

Mean horizontal windspeed profiles within and above a plantation of Japanese larch were obtained. A log-profile analysis of above-vegetation windspeeds yielded a wide range of values for the roughness length parameter (z_0) and the zero plane displacement height (D), with these two parameters being highly correlated with each other. The computed Eulerian space scale of turbulence within the vegetation showed deeper penetration of large eddies after needle fall and during high winds. Power spectra showed that at the base of the plantation most of the variation in windspeed was associated with gusts of about 100 meters wavelength. Power spectra at the most dense portion of the plantation canopy showed considerable modification due to the tree spacing.

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AIR FLOW AND TURBULENCE CHARACTERISTICS IN A JAPANESE LARCH PLANTATION

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L. H. Allen, Jr.

INTRODUCTION

Air flow within and immediately above vegetation couples the land-mass surface source or sink to the larger weather system above. Work at this location in the past has been concerned with the source and sink distribution of water vapor, CO_2, sensible heat, and momentum within various agricultural crops, using both energy balance and momentum balance approaches. This work is a study of the turbulence characteristics within a tall vegetated surface.

In 1964 a study was begun of wind flow within and above a plantation of Japanese larch near Ithaca, N. Y. The sensor system consisted of cup anemometers and heated-thermocouple anemometers for measuring wind flow, and aspirated thermopiles with a time constant of about one minute for measuring temperature profiles above the vegetation.

The Japanese larch was spaced 3 meters by 3 meters and had a mean height of 1040 cm. There was quite a bit of individual variation in heights of the tips of the trees, with a few extending 200 cm above this height. The fetch in the westerly direction was about 150 meters.

The trees were sharply tapered at the tops, with the top 1/3 of the plant-air layer fairly open, the middle 1/3 quite dense, and the lower 1/3 consisting mostly of dense dead branches. Some of the air flow patterns and turbulence characteristics to be discussed later will reflect the effect of this structure of the vegetation.

The wind data were taken on October 30 and 31, after partial needle fall, and on November 10 and 12, after total needle fall. The effects of the needles on the flow pattern and turbulence, while not drastic, do show up in the resulting data.

The total "yield" of needles from this plantation was 2200 pounds per acre. By the evening of October 31, approximately 2/3 of the needles had fallen. However, the remaining 1/3 were distributed well enough so that the drag characteristics of the trees should not have been changed too much from that of a fully needled tree. Certainly on a tree such as larch, every needle cannot function independently as a drag surface.

The computed total needle surface area per unit ground area (LAI) was 9.36. This gives an average leaf area density of about 0.013 cm^2/cm^3, assuming equal distribution over 700 cm of depth. No attempt was made to evaluate the surface area of the branches and trunks.

Four Beckman & Whitley cup anemometers and 6 Thornthwaite cup anemometers were used above the vegetation. Six Hastings-Raydist heated-thermocouple anemometers with probe types N-7 or N-7B were used within the vegetation. The cup anemometer data were read from banks of electromechanical counters, with sampling durations of 10 minutes usually. The heated-thermocouple signals were recorded on an analog magnetic tape recorder. Later these data were converted to digital form and stored on magnetic tape for further processing.

Table 1 gives the height of the sensor systems used in this study. The wind data were taken at heights ranging from 1569 cm down to 115 cm. The juncture of the cup and the heated-thermocouple anemometer system was at 1040 cm.

WINDSPEED PROFILES

Thirteen runs were made with both cup and heated-thermocouple anemometers. Several other runs were made using cup anemometers only. Table 2 contains the average windspeed data. The windspeed data obtained at a height of 1040 cm were different for the heated-thermocouple anemometer than for the cup anemometer, a fact commonly noted even though the heated-thermocouple anemometer had been carefully calibrated. Figure 1 shows the average normalized windspeed obtained from the October 30 and 31 data. The windspeed profile appears nearly linear within the vegetation in the lower 2/3 of its depth. Figure 2 shows the same thing for November 12, 1964. All data were normalized with respect to the lowest cup anemometer. These figures also show a tendency for the windspeed to increase toward the bottom of the vegetation. Tentatively, this behavior is explained on the basis of three factors, all of which are dependent upon the low density of plant parts near the ground. First, the fetch for this site was inadequate, but it was the best that could be found in the Ithaca area. This fact would allow gusts to blow through the bottom of the plantation. Secondly, there were occasional holes in the plantation where a pressure pulse or gust of wind could penetrate to the bottom and from there, with most of the effect appearing where there would be less obstruction to flow. Thirdly, the slope of the site had at this point at least a 3% downslope in the direction of the prevailing winds (west). Anyhow, these profiles indicate that downward transfer of horizontal momentum through the vegetation cannot account for all of the flow within the vegetation, an assumption that has frequently been used with short, dense vegetation.

The cup anemometer data were subjected to computer-programmed log-profile law analysis according to a procedure by Covey (1963), which was adapted from a personal communication from Robinson and Tanner. No buoyancy corrections were made since all of the cup anemometer data were obtained near the top of the vegetation, and because of the shape of the temperature profiles obtained. The temperature profiles showed a maximum value about 1 meter above the top of the vegetation, with decreasing temperatures above

and below. The decrease below was attributed to evaporation and transpiration from plant parts; all data were taken after rains which left trunks, branches, and needles visibly wet. However, the maximum value of the temperature profile at about 1 meter above the mean height of the vegetation is an anomally which may be due to taller trees upwind or to net upward movement of air due to slowing down of winds within the vegetation.

Typical values for the zero-plane displacement height and for the roughness length parameter were 635 cm and 112 cm respectively. Table 3 shows the results of the log-profile analysis. Figure 3 shows the relationship of u*, the friction velocity, to windspeed at the uppermost height of 1569 cm. The slope of the best fit relationship passing through the zero points is 0.189 (when the same units are used on both axes) as indicated in Figure 3.

Earlier work by Stoller and Lemon (1963) showed some changes in surface characteristics of flexible vegetation, such as alfalfa, wheat, and corn, as reflected in the parameters zero-plane displacement height (D) and roughness length parameter (z_o), with increasing windspeed. One would not expect very much change in the surface drag characteristics of a stiffer vegetation such as Japanese larch with increasing windspeed. Certainly the zero-plane displacement height would not be expected to change very much with windspeed due to a "bending over" or deforming of the plant structure.

Figure 4 shows the effect of changing windspeed on z_o. The fit is not too good, but a definite trend exists, with a correlation coefficient of 0.48. Figure 5 shows the zero-plane displacement height plotted against windspeed. The correlation here is better. However, part of the goodness of fit of these data may be due to the coupling of the higher windspeed data with the situation where all of the needles have been dropped from the trees.

Figure 6 shows the very strong correlation of z_o with displacement height, with r =-0.95. Any further work with multiple correlations can only increase r by a negligible amount. Also, Figure 7 shows the strong correlation of z_o with u*, and Figure 8 the strong correlation of u* with D. Analyses of variance of the data in Figures 6, 7 and 8 all indicate that the regression line is significant at the .01 level.

The regression lines all follow the pattern found by Stoller and Lemon (1963) for corn.

The reason for z_o and displacement height varying together with windspeed may be an artifact of the method of computation rather than having any real physical significance. In the log-profile law,

$$\bar{u} = \frac{u^*}{k} \ln \frac{(z + D)}{z_o}$$

if a defined drag coefficient remains anywhere near constant with windspeed, then it would be required that

$$\frac{u^*}{\bar{u}} = \text{constant},$$

which in turn would require $(z + D)/z_o$ to remain constant. Hence, any change in D in any fitting procedure would require a change in z_o to maintain a reasonably constant ratio, $u^*/\bar{u}$. However, the z_o vs. u^* and u^* vs. D relationships are not easily explained from the form of the log profile formula.

The log profile parameters $u^*/\bar{u}_{1569}$, z_o, and D were compared also by dates (October 30 and 31 vs. November 12), which reflected needle amount, and by wind direction. The first two parameters showed no significant variation due to either date or wind direction. Displacement height did show significance at the .05 F-level for both date and wind direction. However, this result may be confounded by windspeed dependence as shown in Figure 5.

The various relationships indicated in Figures 3 through 8 were also investigated by regression analyses for October 30 and 31, November 10 and 12, November 10, and November 12 alone. The general tendencies were supported in most cases. Especially did the u^*, z_o, and D relationships maintain a high level of significance.

STATISTICAL PROPERTIES OF TURBULENCE

Figure 9 shows how the computed Eulerian space scale of turbulence, (using the heated-thermocouple anemometers)

$$L_x = \bar{u} \int_0^\infty R(t)\, dt$$

changed within the vegetation. The values are quite constant within the vegetation, regardless of whether windspeeds were high or low, or whether needles were present or missing. There was a slight tendency for values to be higher at the higher windspeeds and with no needles present.

The biggest change occurred at the 725 cm height. The tremendous increase here is attributed to the more open vegetation after needle-fall and to the deeper penetration of eddies before they are broken up. The range of the eddy scale was about 2 to 8 meters. As we shall see from power spectra given later this corresponds to a shorter eddy scale than one is usually most aware of under gusty, windy conditions.

Turbulent intensity (coefficient of variation), skewness, kurtosis, and cross-correlation coefficients with respect to the top-most heated-

thermocouple anemometer were computed for each run and then averaged. Table 4 lists the average values at the six anemometer heights.

In all cases, the distribution of windspeeds are skewed toward lower windspeed values, as indicated by a positive skewness. The greatest skewness shows up at the 725-cm anemometer, which is in the most dense part of the vegetation.

The average kurtosis shows a tendency toward a platykurtic distribution in all cases. However, the windspeed at the topmost anemometer shows only a small deviation from that expected by a normal distribution. Again, the windspeed at 725 cm shows the greatest deviation. It has a very definite platykurtic distribution. At this level, apparently the anemometer was responding well to large-scale eddies, but then behaved more like the lower anemometers once the gust passed by.

For some of the runs, the cross-correlation coefficient was actually negative for the bottom two anemometers. This would indicate that the vertical distance is large enough for the variations in windspeed to tend to get out of phase with respect to the topmost anemometer.

Time-lagged cross-correlation coefficients should be computed to find the time required for eddies to penetrate to given levels.

POWER SPECTRA

Power, or energy, spectra were obtained from the windspeed data following a modified procedure of Blackman and Tukey (1958), as presented in Pasquill's ATMOSPHERIC DIFFUSION (1962). In order to shorten computing time, the spectra obtained are composite spectra, obtained as indicated by Griffith, Panofsky, and Van der Hoven (1956) and by Jones (1957) M.R.P. #1044. The point at which the two sections overlap is at 0.3 cps in the following figures. The spectra have been corrected to the first approximation for linear trends in the data based on the treatment by Webb (1955). The correction was applied to the autocovariance function. Likewise, the spectra were corrected for sampling duration and for averaging time as outlined by Pasquill (1962). Prewhitening of the data was tried and rejected. It tended, in these cases, to vastly overemphasize the magnitude of the spectrum function at low frequencies. The technique presented by Pasquill (1962) was the one tried. Aliasing of the data was no problem because the filtering action of the thermocouple anemometer prevented frequencies higher than that allowed by the sampling time from entering. The response time of the anemometers was 1 second, whereas the sampling time was 0.16 second. No attempt was made to estimate the statistical reliability of the various points in these spectra.

Figure 10 shows the spectra obtained during the first 10-minute run on October 30, 1964. The values plotted are nF(n) normalized on the basis of the maximum value of nF(n), as a function of frequency in cycles per second. The windspeed at the uppermost cup anemometer (at 1569 cm) was 371 cm/sec. In each of the spectra at the six heights, there is

a pronounced low-frequency peak at about 0.04 cps, corresponding to a period of about 25 seconds. This peak is associated with gusts or eddies of about 100 meters wavelength.

One striking feature of the spectrum at a height of 115 cm is that there is very little contribution to the variance of windspeeds at higher frequencies. This means that at the floor of this forest there is less turbulence on a small scale and that most of the variation in horizontal air flow is due to pressure waves associated with larger scale eddies.

At the higher frequencies there are some less well-developed peaks in the spectra appearing between periods of 3 to 7 seconds. Since the mean windspeeds at these levels were about 100 cm/sec, and were probably lower during periods between gusts, these peaks are probably due to local eddies created by individual trees. The spacing between trees would be about 3 to 4 meters, depending on whether the wind direction was in line or on the diagonal with the rows of trees.

Two other examples of power spectra at the 6 heights are in the next two figures. The power spectra shown in Figure 11, obtained on October 31, 1964 at 1430 to 1440 EST, shows the same trends mentioned in Figure 10. The mean windspeed at 1569 cm was 341 cm/sec. The period between large gusts was about 21 seconds, giving an eddy scale length of more than 70 meters.

In both Figure 10 and Figure 11 there appears to be a kind of transition zone at a height of 725 cm, where the density of plant parts is greatest. More of the fluctuations are due to higher frequency components, having periods of the order of 3-seconds. The average windspeed was about 60 cm/sec in Figure 11, which indicates an eddy scale of about 180 cm.

The third figure of this series (Figure 12) shows spectra under conditions of high windspeed, about 837 cm/sec at a height of 1569 cm. The low frequency spectra maxima occurs at a period of about 10 seconds, which yields an eddy scale length of above 80 meters. This figure also shows very little contribution at very low frequencies (less than 0.02 cps). The spectrum at a height of 115 cm has a shape that would be associated with an exponentially decreasing autocorrelation coefficient.

CONCLUSIONS

In conclusion, three points can be emphasized. First, the application of the log-profile law to these data leads to a lot of variation in z_0, u* and D, most of which appears to be closely correlated each with the other. Even though D is lower at higher windspeed, this effect may be related also to the lack of needles on the stand when windspeeds were high. The fact that D may be quite a bit lower was also indicated by Figure 9 which showed the tremendous increase of the Eulerian space scale of turbulence at the 725-cm height. This latter fact was the second point of this study.

Thirdly, the power spectra types show a pronounced peak corresponding to wavelengths approaching 100 meters. Most of the variation of windspeed at

the bottom of the stand (115 cm) appears to be associated with these large-scale gusts, for reasons mentioned earlier in the paper. In the region of maximum density of plant parts, the spectra show increased relative contributions from small-scale eddies which have length scales corresponding to the tree spacing distances.

The type of turbulence data presented here are currently being analyzed for several agricultural crops (oats, corn, soybeans and sunflower). Eventually relationships between the vegetation height and structure and the turbulence and exchange processes will be obtained.

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Table 1. Anemometer and thermocouple heights (cm) in 1964 Japanese larch.

Anemometer System			
Beckman & Whitley cup	Thornthwaite cup	Hastings Heated-thermocouple	Temperature system
1569	1340	1040	1510
1492	1260	875	1280
1416	1180	725	1130
1340	1100	575	1030
	1060	345	
	1040	115	

Table 2. Average windspeeds (cm/sec) obtained above and within Japanese larch. The dates and times of the run numbers are indicated in Table 3.

Run	Heated-thermocouple anemometers						Cup anemometers								
	Anemometer heights (cm)														
No.	115	345	575	725	875	1040	1040	1060	1100	1180	1260	1340	1416	1492	1569
70	53	53	55	60	96	149	204	210	235	272	295	322	343	360	371
71	54	57	61	73	120	169	243	253	274	312	333	358	383	407	418
72	45	49	53	56	84	132	199	209	229	265	286	308	328	349	362
A							266	280	301	332	358	380	393	408	436
73	55	52	73	97	169	248	289	302	326	362	386	412	461	477	487
74	60	56	66	76	128	184	236	247	264	289	308	328	346	360	372
75	33	47	55	58	100	--	208	216	230	260	276	294	318	334	341
C							227	232	246	268	280	302	323	337	341
D							190	196	210	231	248	263	275	289	296
E							209	220	239	268	282	300	316	329	338
76	27	24	41	60	82	120	176	180	193	209	218	224	239	246	248
F							352	360	380	410	437	459	482	498	517
77	172	143	178	274	328	339	474	485	511	553	588	617	644	672	698
78	214	186	214	332	332	383	553	565	596	647	691	730	773	806	837
79	216	193	217	331	363	382	584	604	634	670	724	754	783	809	838
80	204	132	199	307	327	348	521	537	569	612	662	703	739	771	807
81	131	138	151	174	264	--	456	460	480	531	571	602	625	649	678
82	132	127	147	196	243	--	401	409	436	476	507	544	569	596	628

Table 3. Log profile parameters for 1964 Japanese larch.

Date	Run No.	Mean wind direction (degrees)	u* (cm/sec)	z_o (cm)	/D/ (cm)	$\bar{u}_{1569}$ (cm/sec)
Oct. 30	70	292	57.7	57.1	809	371
Oct. 30	71	292	84.8	128.8	633	418
Oct. 30	72	292	62.7	81.3	750	362
Oct. 31	A	345	57.2	39.2	784	436
Oct. 31	73	334	119.8	206.7	494	487
Oct. 31	74	334	53.7	52.2	733	372
Oct. 31	75	299	65.0	112.4	635	341
Nov. 10	C	307	73.5	169.0	460	341
Nov. 10	D	292	40.4	42.9	760	296
Nov. 10	E	292	35.3	15.1	877	338
Nov. 10	76	319	20.8	5.8	870	248
Nov. 12	F	193	80.9	74.1	618	517
Nov. 12	77	200	118.8	96.6	562	698
Nov. 12	78	200	197.7	221.6	362	837
Nov. 12	79	200	109.9	42.3	682	838
Nov. 12	80	200	192.4	223.3	378	807
Nov. 12	81	200	111.3	83.7	618	678
Nov. 12	82	200	164.2	274.7	310	628

Table 4. Averages of turbulent intensity, skewness, kurtosis, and cross-correlation coefficient with respect to the topmost heated-thermocouple anemometer at the indicated heights in Japanese larch vegetation, 1964.

Height (cm)	Turbulent intensity	Skewness	Kurtosis	Cross-correlation coefficient
1040	.47	.50	3.05	1.00
875	.54	1.11	4.71	.62
725	.57	1.62	8.16	.44
575	.51	.94	4.42	.22
345	.57	.82	4.47	.19
115	.51	.81	4.92	.13

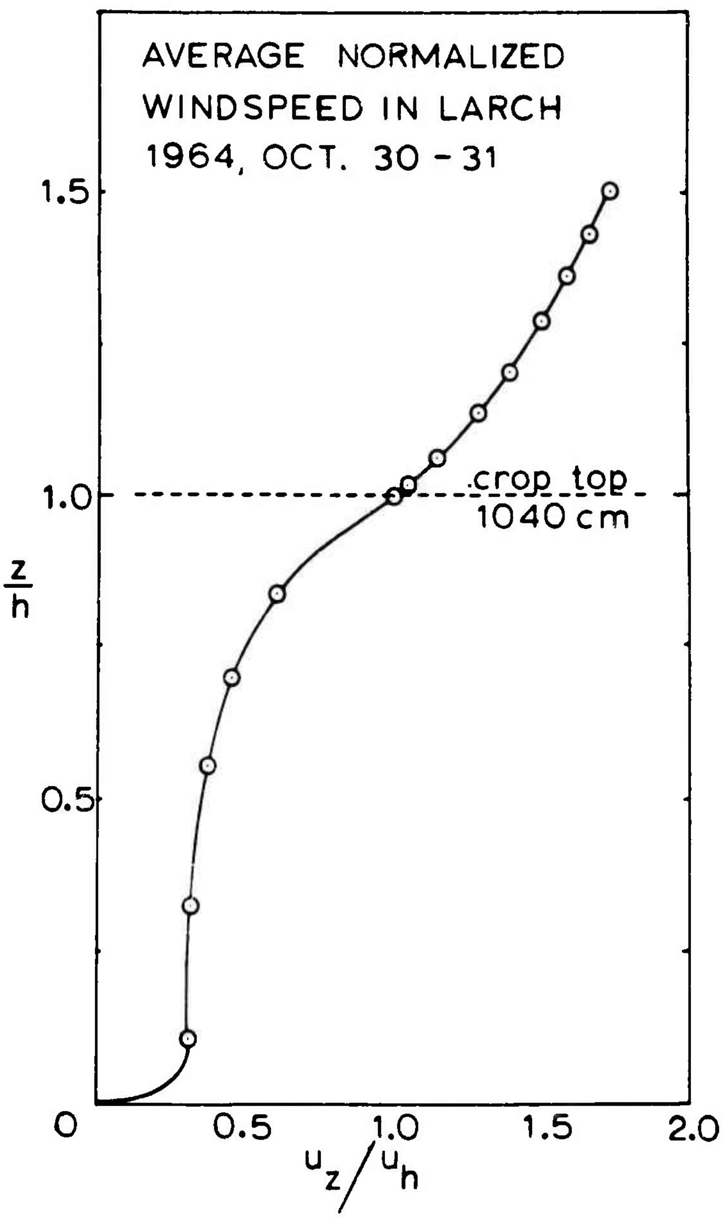

Fig. 1. Average normalized windspeed above and within Japanese larch near Ithaca, N. Y., Oct. 30 and 31, 1964.

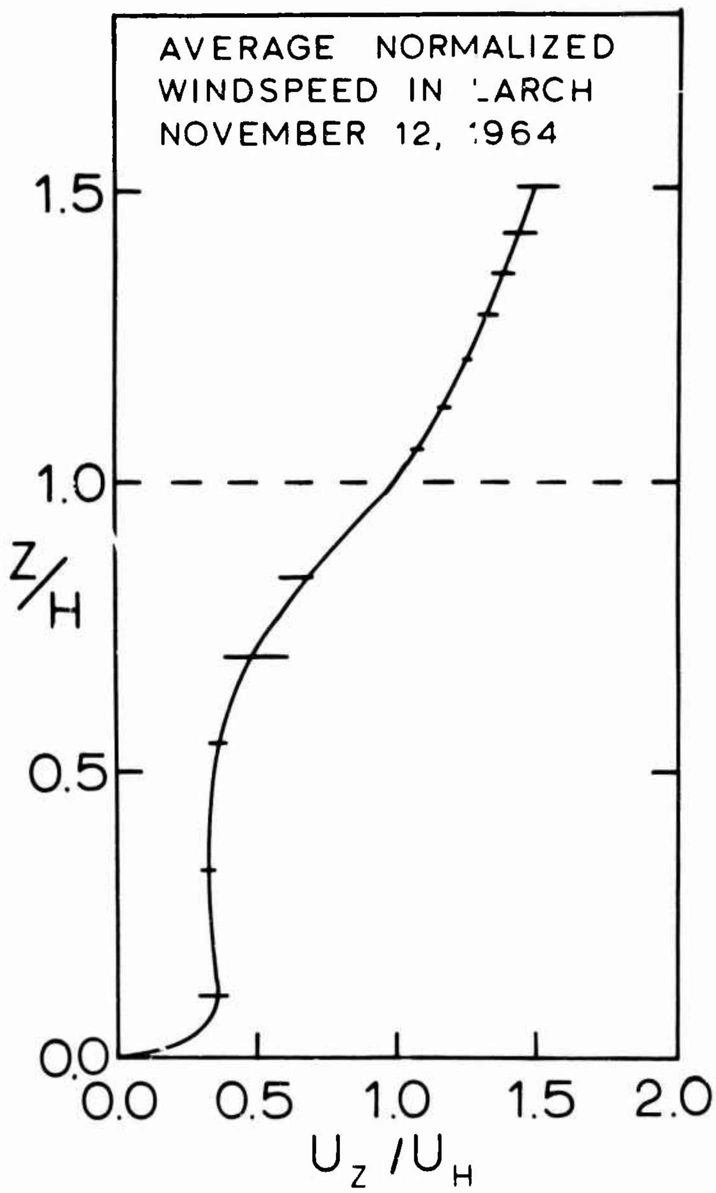

Fig. 2. Average normalized windspeed above and within Japanese larch near Ithaca, N. Y., Nov. 12, 1964.

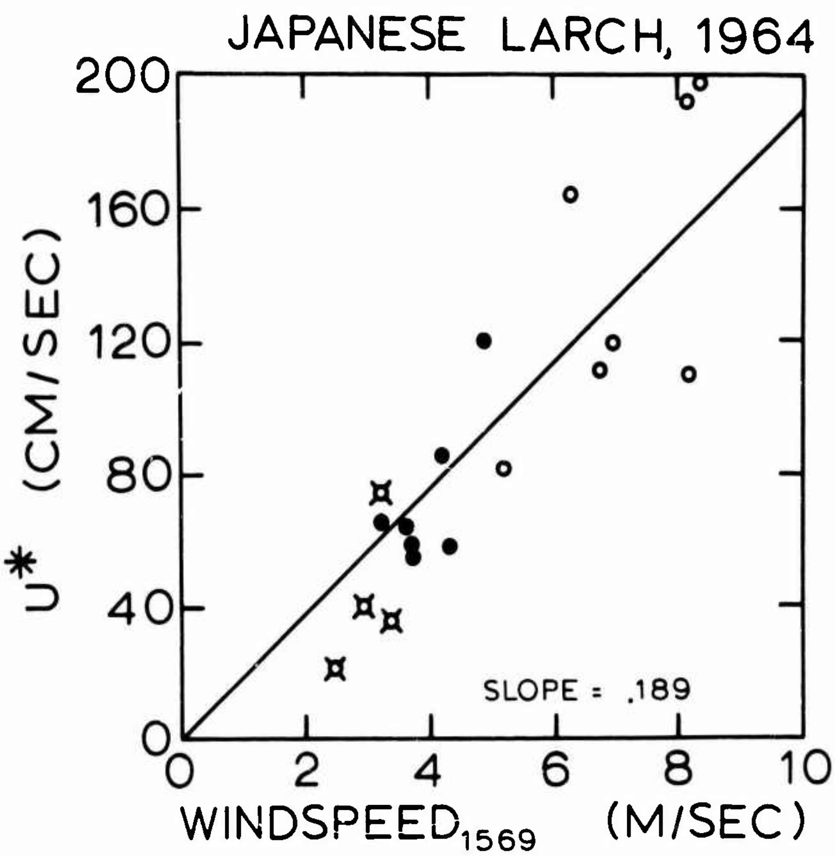

Fig. 3. Friction velocity, u*, as a function of windspeed at the 1569-cm height in 1964 in Japanese larch near Ithaca, N. Y. The solid dots indicate data on Oct. 30 and 31, the crossed open circles data on Nov. 10, and the open circles data on Nov. 12.

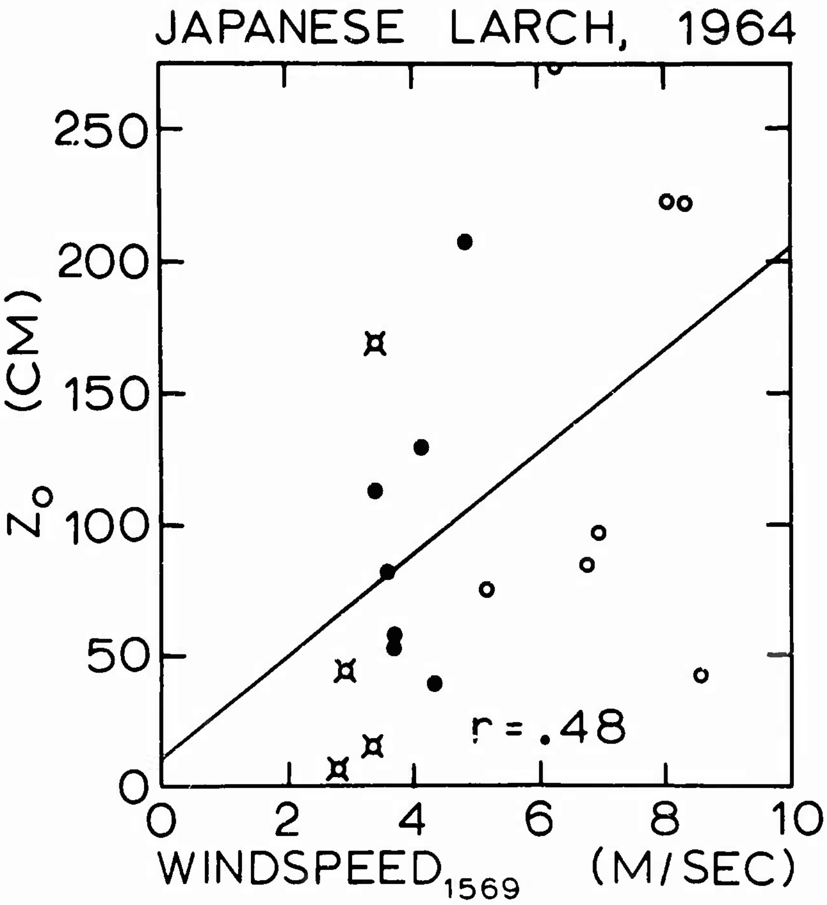

Fig. 4. Roughness length parameter, z_0, as a function of windspeed at the 1569-cm height in 1964 in Japanese larch near Ithaca, N. Y. The solid dots indicate data on Oct. 30 and 31, the crossed open circles data on Nov. 10, and the open circles data on Nov. 12.

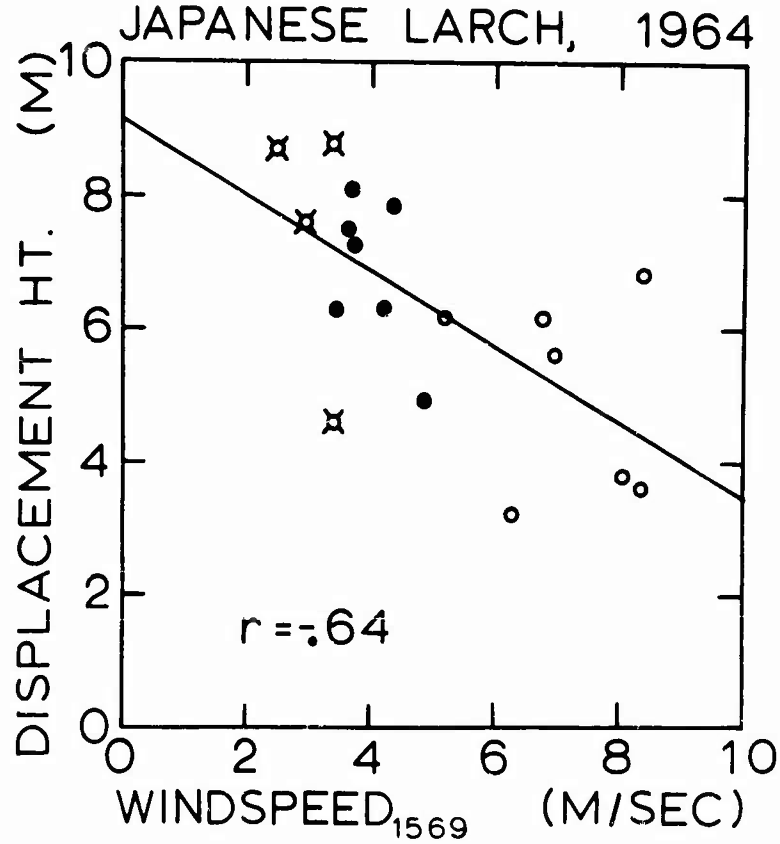

Fig. 5. Zero-plane displacement height as a function of windspeed at the 1569-cm height in 1964 in Japanese larch near Ithaca, N. Y. The solid dots indicate data on Oct. 30 and 31, the crossed open circles data on Nov. 10, and the open circles data on Nov. 12.

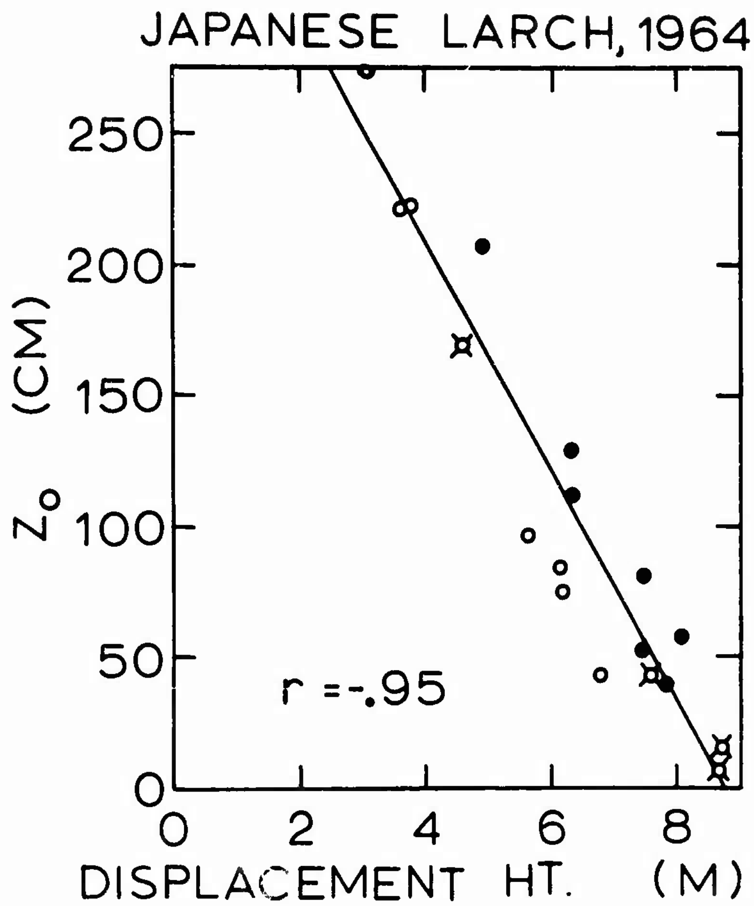

Fig. 6. Relationship between the roughness length parameter, z_o, and zero-plane displacement height in 1964 in Japanese larch near Ithaca, N. Y. The solid dots indicate data on Oct. 30 and 31, the crossed open circles data on Nov. 10, and the open circles data on Nov. 12.

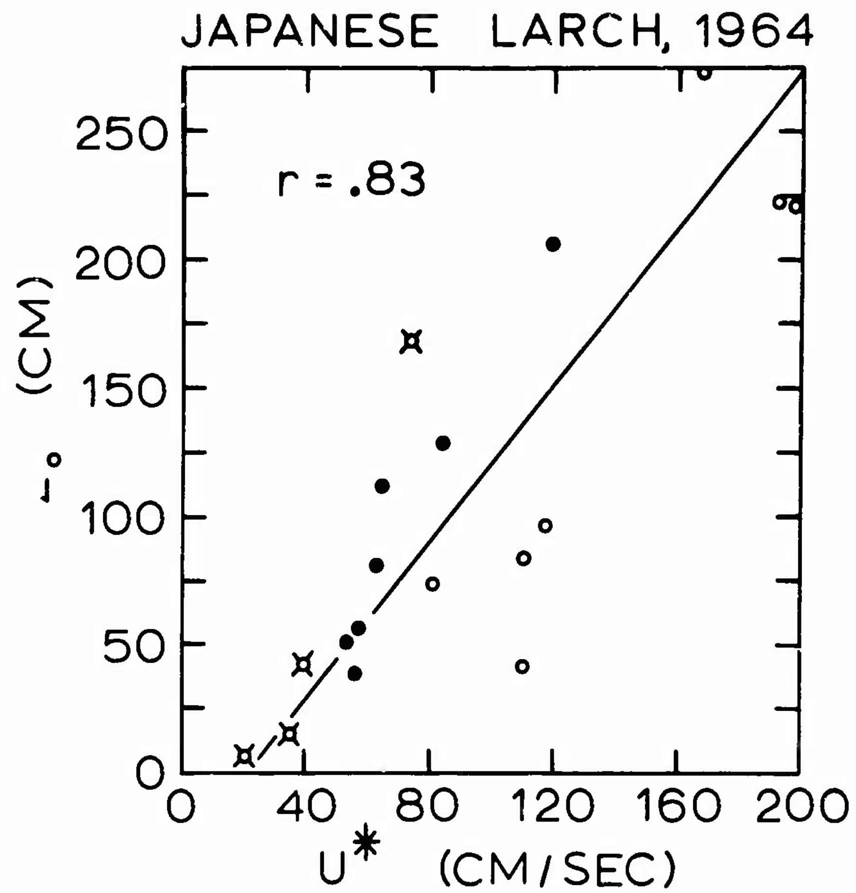

Fig. 7. Relationship between the roughness length parameter, z_o, and the friction velocity, u*, in 1964 Japanese larch near Ithaca, N. Y. The solid dots indicate data on Oct. 30 and 31, the crossed open circles data on Nov. 10, and the open circles data on Nov. 12.

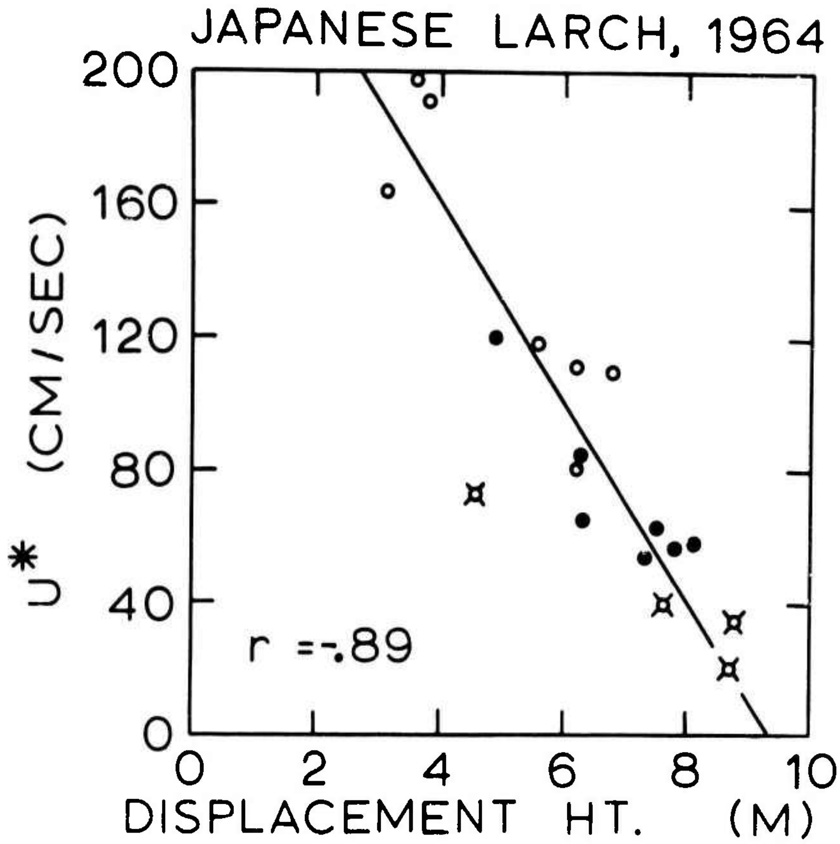

Fig. 8. Relationship between the friction velocity, u*, and the zero-plane displacement height in 1964 Japanese larch near Ithaca, N. Y. The solid dots indicate data on Oct. 30 and 31, the crossed open circles data on Nov. 10, and the open circles data on Nov. 12.

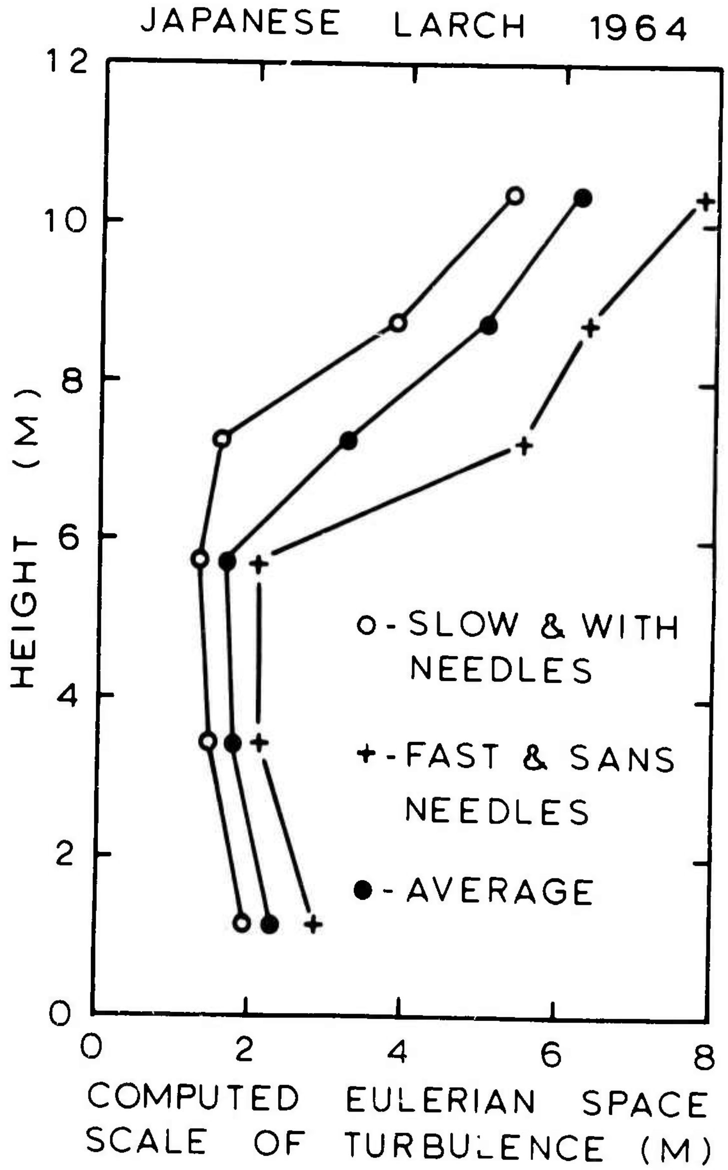

Fig. 9. Averaged computed Eulerian space scale of turbulence in 1964 in Japanese larch near Ithaca, N. Y.

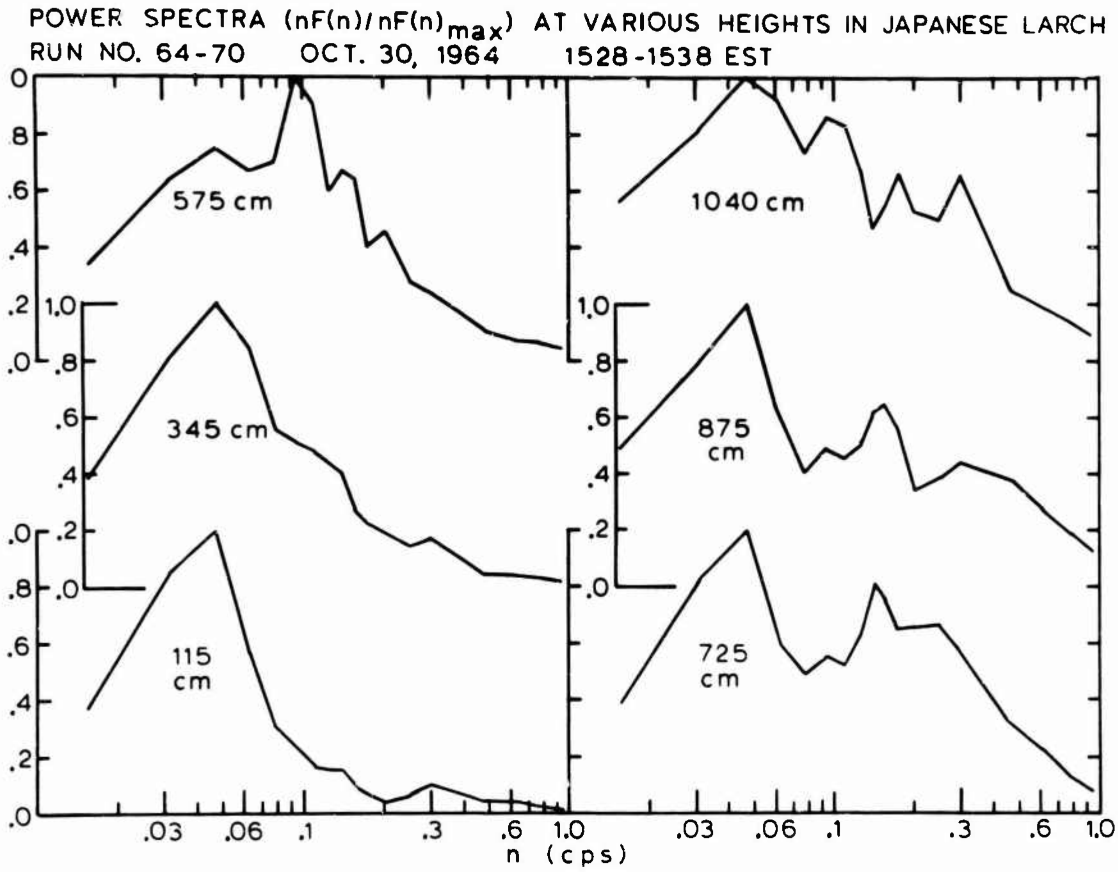

Fig. 10. Composite, normalized power spectra at the indicated heights obtained from heated-thermocouple anemometer data in 1964 in Japanese larch near Ithaca, N. Y.

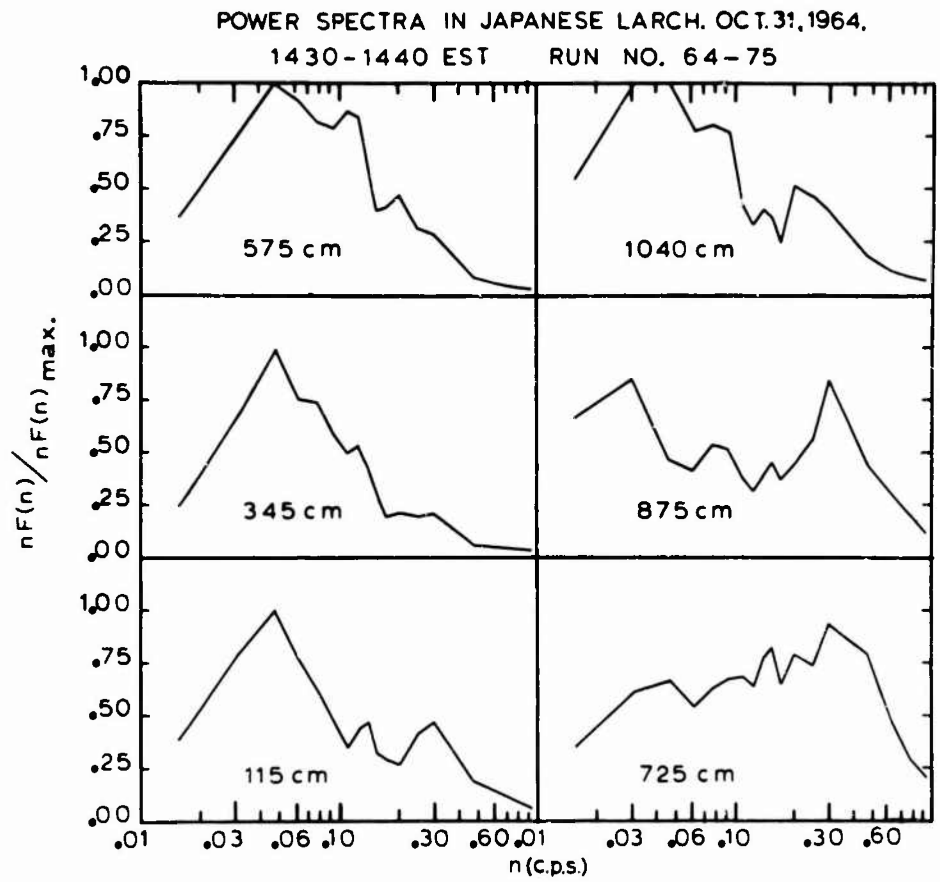

Fig. 11. Composite, normalized power spectra at the indicated heights obtained from heated-thermocouple anemometer data in 1964 in Japanese larch near Ithaca, N. Y.

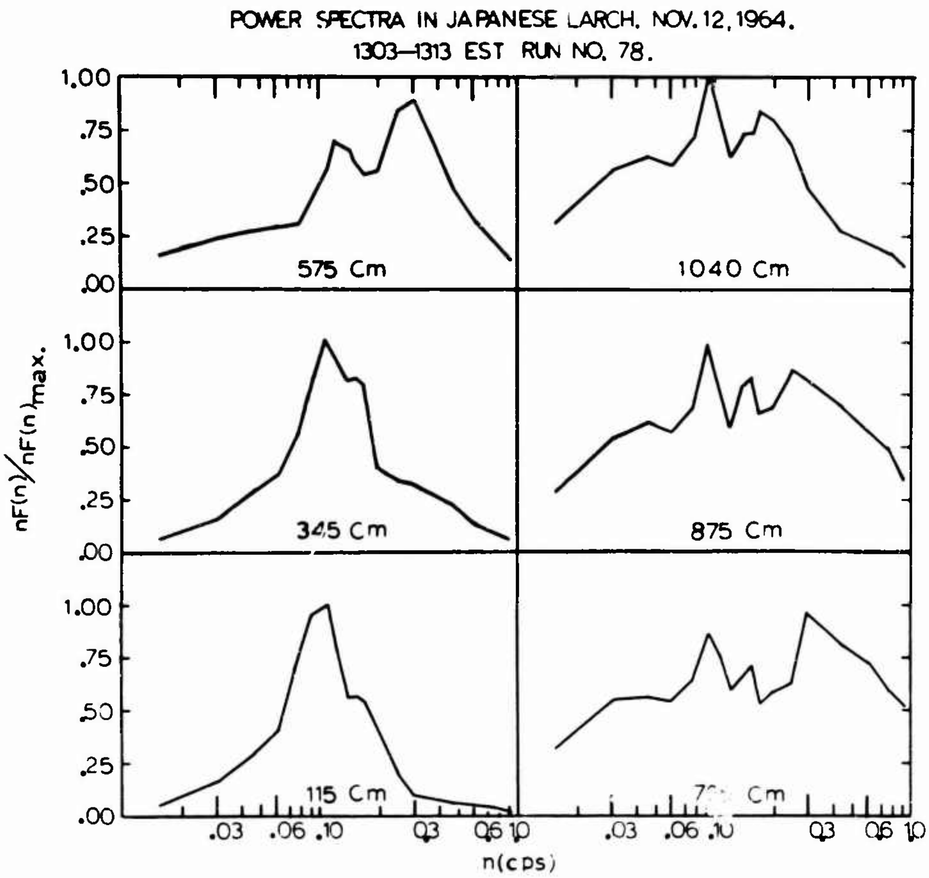

Fig. 12. Composite, normalized power spectra at the indicated heights obtained from heated-thermocouple anemometer data in 1964 in Japanese larch near Ithaca, N. Y.

APPENDIX

This appendix gives a listing of the FORTRAN computer program used to compute power spectra with the Cornell University Control Data Corporation 1604 digital computer.

This program was designed with several features which should be pointed out. First, it was set up with the ability to compute spectra across up to three wavelength ranges, or stages, as indicated in the program. This feature reduces computing time tremendously, and prevents overtaxing of computer storage capability.

The second feature permits a correction to be applied to remove the effect of a linear trend in the data upon the power spectra. The third feature allows one to vary a "prewhitening" factor by changing one card. The fourth feature is the correction for finite averaging time and finite sampling duration.

This program was designed specifically for working with windspeed stored on data magnetic tape in a particular "format." However, since it is written with many subroutines, it is possible to modify the program for other forms of data input and other types of data.

The subroutine "CRACK" was written by David Bessel, Department of Computer Science, Cornell University, Ithaca, N. Y.

The program was written by Alvin Kaskel, Therm Advanced Research, Inc., Ithaca, N. Y.

APPENDIX

```
      PROGRAM PSPECTRA
C
C     CONTROL IDENTIFICATION
C
C             NSTAGE = INTEGER REPRESENTING THE PERIOD OF THE
C                      NON-OVERLAPPING MEANS TO BE ANALYZED
C                      NSTAGE=1 IS THE RAW DATA
C
C             NSTAGECO = INTEGER EQUAL TO AN NSTAGE TO WHICH  THE
C                        ANALYSIS IS TO BE COMPARED. USED TO DETERMINE
C                        THE NUMBER OF POINTS IN THE ANALYSIS
C
C             INDEXQ = 1 USE NON-ADJUSTED COVARIANCES
C                    = 2 USE ADJUSTED COVARIANCES
C
C             ICROPCHG = 1 OATA IS FOR SAME CROP AS PREVIOUS ANALYSIS
C                      = 2 DATA IS FOR NEW CROP
C
C     NOTE
C
C          PROGRAM ALWAYS ASSUMES THAT THE STARTING POINT NUMBER FOR A
C          RUN IS FOR DATA IN CHANNEL 1 AND THAT THE FINISHING POINT
C          NUMBER IS FOR DATA IN CHANNEL 7
C
      TYPE REAL LH,NFN,NFFN,NFNR,NFFNR,NPFN,NPFFN
      COMMON/NUMBERS/NBS,NPS,NBF,NPF,M,NP,NSTAGE,INDEXQ,NJ,NDATA,TFAC,
     *               OELTAT
      COMMON/CHANNELS/ICHUSE(7),IANUSE(7),ISAVE(7)
      COMMON/XSUMS/XX(31,7),XI(31,7),XK(31,7),XS(1000,7),DATA(62,7),
     *             XT(31,7),XJ(31,7),TJ(31,7),XTBAR(7),S(7)
      COMMON/ANEMFACS/U(255,7),ALPHA(7),BETA(7),A(7),B(7),C(7),O(7),
     *                E(7),F(7),G(7),H(7)
      COMMON/VALUES/QK(31),OKK(31),LH(31),UH(31),FNQ(31),FN(31),FFN(31),
     *              NFN(31),NFFN(31),NFNR(31),NFFNR(31),NPFN(31),
     *              NPFFN(31),VH(31),FREQ(31),SIG(31),SUML
      COMMON/EXTRAS/VV(7),VEL(7),VELS(7),NSTAGECO
      COMMON/I/NUMPER,NUMBLOCK,NUMPNTS,IFLAG,ICHANNEL(1680),IDATA(1680)
      DIMENSION ICHT(7),IWHT(7),FZ(7),IANO(7),ITCNO(7),ITNO(7),
     *          CROPIOEN(10)
 1000 FORMAT(16I5)
 1010 FORMAT(2F10.5,F15.5,3E15.5/20X,4E15.5)
 1020 FORMAT(5I5,F10.5)
 1030 FORMAT(10A8)
 1040 FORMAT(8F10.5)
 1050 FORMAT(1H1,40X,39HPOWER SPECTRA ANALYSIS OF RAW WINO DATA)
 1060 FORMAT(1H1,26X,46HPOWER SPECTRA ANALYSIS OF RAW WIND OATA USING ,
     *       20HADJUSTED COVARIANCES)
 1070 FORMAT(1H1,34X,44HPOWER SPECTRA ANALYSIS OF PRE-WHITENED WIND ,
     *       7HOATA,B=,F4.2)
 1080 FORMAT(1H1,20X,44HPOWER SPECTRA ANALYSIS OF PRE-WHITENEO WINO ,
     *       34HDATA USING ADJUSTED COVARIANCES,B=,F4.2)
 1090 FORMAT(1H ,19X,10A8,/)
 1100 FORMAT(1H ,2X,8HCROP HT.,5X,1HZ,5X,4HF(Z),3X,9HANEM. NO.,2X,
     *       8HTAPE NO.,2X,14HTAPE CHAN. NO.,3X,4HLAGS,3X,
     *       13HSAMPLING TIME,3X,8HRUN TIME,3X,16HAVERAGING PERIOD)
 1110 FORMAT(1H ,I7,4H CM.,I6,4H CM.,F6.4,I9,I10,I12,I13,F10.2,5H SEC.,
     *       F10.2,5H SEC.,F9.2,5H SEC.)
 1120 FORMAT(1H0,41X,8HADJUSTED,/,14X,5HSIGMA,8X,7HQ SUB K,9X,7HQ SUB K,
     *       9X,7HL SUB H,9X,7HU SUB H)
 1130 FORMAT(1H ,3X,5F16.7)
```

```
 1140 FORMAT(1H0,41X,8HADJUSTED,/,14X,5HSIGMA,8X,7HO SUB K,9X,7HQ SUB K,
     *        9X,7HL SUB H,9X,7HV SUB H,9X,7HU SUB H)
 1150 FORMAT(1H ,3X,6F16.7)
 1160 FORMAT(1H0,13X,5HSIGMA,6X,11HFREQUENCY,N,4X,12HF(N)*O SUB 0,10X,
     *        4HF(N),11X,6HN*F(N),4X,18HN*F(N)/(N*F(N))MAX,2X,
     *        11HN**5/3*F(N))
 1170 FORMAT(1H ,3X,7F16.7)
 1180 FORMAT(1H0,59X,8HADJUSTED,8X,8HADJUSTED,8X,8HADJUSTED,8X,
     *        8HADJUSTED,/,14X,5HSIGMA,6X,11HFREQUENCY,N,26X,4HF(N),11X,
     *        6HN*F(N),4X,18HN*F(N)/(N*F(N))MAX,2X,11HN**5/3*F(N))
 1190 FORMAT(1H ,3X,2F16.7,16X,4F16.7)
 1200 FORMAT(1H0,57X,9HCORRECTED,/,9X,11HSUM L SUB H,6X,10HU (CM/SEC),
     *        4X,14HSUM OF SQUARES,2X,14HSUM OF SQUARES,3X,10HVARIANCE,V,
     *        11X,3HRMS,13X,5HRMS/U,/,4X,7F16.7)
 1210 FORMAT(1H0,89X,8HADJUSTED,9X,8HADJUSTED,/,14X,5HSIGMA,9X,6HLOG(N),
     *        12X,5HN*Z/U,7X,8HV*N*F(N),7X,13HV*N*F(N)/U**2,4X,
     *        8HV*N*F(N),7X,13HV*N*F(N)/U**2)
 1220 FORMAT(1H ,3X,F16.7,7X,9H-INFINITY,5F16.7)
 1230 FORMAT(1H ,3X,7F16.7)
 1240 FORMAT(1H1,45HTHERE IS NOT SUFFICIENT DATA TO MAKE A POWER ,
     *        16HSPECTRA ANALYSIS)
      NUMBLOCK=0
   10 READ 1000,(ICHUSE(I),I=1,7)        $ READ 1000,(IANUSE(I),I=1,7)
      READ 1010,(ALPHA(I),BETA(I),A(I),B(I),C(I),D(I),E(I),F(I),G(I),
     *          H(I),I=1,7)
      DO 30 I=1,7
      IF (ICHUSE(I)) 30,30,20
   20 READ 1020,ICHT(I),IWHT(I),IANO(I),ITNO(I),ITCNO(I),FZ(I)
   30 CONTINUE
      CALL VELCOREL
   40 READ 1030,(CROPIDEN(I),I=1,10)
      READ 1000,NBS,NPS,NBF,NPF,M,NSTAGE,NSTAGECO,INDEXO
      READ 1040,TFAC,DELTAT
      CALL ENDPOINT                      $ CALL YSETUP
      CALL PHASESUM                      $ IF (NDATA) 270,270,50
   50 DO 260 J=1,7
      IF (ICHUSE(J)) 260,260,60
   60 IF (TFAC-0.0000001) 70,70,80
   70 GO TO (90,100),INDEXO
   80 GO TO (110,120),INDEXO
   90 PRINT 1050                         $ GO TO 130
  100 PRINT 1060                         $ GO TO 130
  110 PRINT 1070,TFAC                    $ GO TO 130
  120 PRINT 1080,TFAC
  130 IF (NSTAGE-1) 140,140,150
  140 PER=DELTAT                         $ TAU=NP*DELTAT
      GO TO 160
  150 II=(M/2)**(NSTAGE-1)               $ PER=II*DELTAT
      TAU=II*NP*DELTAT
  160 PRINT 1090,(CROPIDEN(I),I=1,10)
      PRINT 1100
      PRINT 1110,ICHT(J),IWHT(J),FZ(J),IANO(J),ITNO(J),ITCNO(J),M,
     *          DELTAT,TAU,PER
      NJ=J                               $ CALL OSUBKS
      CALL LSUBH                         $ IF (TFAC-0.0000001) 180,180,170
  170 CALL VSUBH
  180 CALL USUBH                         $ CALL FANDN
      SPEED=VEL(J)/NP                    $ SS=VELS(J)
      CSS=SS-VEL(J)**2/NP                $ VAR=(SS-VEL(J)**2/NP)/NP
      RMS=SQRTF(VAR)                     $ RMSR=RMS/SPEED
```

```
      PRINT 1200,SUML,SPEED,SS,CSS,VAR,RMS,RMSR
      NK=M+1                              $ IF (TFAC-0.0000001) 190,190,210
  190 PRINT 1120
      DO 200 I=1,NK
      PRINT 1130,SIG(I),QK(I),QKK(I),LH(I),UH(I)
  200 CONTINUE
      GO TO 230
  210 PRINT 1140
      DO 220 I=1,NK
      PRINT 1150,SIG(I),QK(I),QKK(I),LH(I),VH(I),UH(I)
  220 CONTINUE
  230 PRINT 1160
      DO 240 I=1,NK
      PRINT 1170,SIG(I),FREQ(I),FNQ(I),FN(I),NFN(I),NFNR(I),NPFN(I)
  240 CONTINUE
      PRINT 1180
      DO 250 I=1,NK
      PRINT 1190,SIG(I),FREQ(I),FFN(I),NFFN(I),NFFNR(I),NPFFN(I)
  250 CONTINUE
      PRINT 1210
      DO 255 I=1,NK
      IF (I-1) 252,252,251
  251 AA=LOGF(FREQ(I))
  252 BB=FREQ(I)*IWHT(J)/SPEED
      CC=VAR*NFN(I)                       $ DD=VAR*NFFN(I)
      EE=RMSR**2*NFN(I)                   $ FF=RMSR**2*NFFN(I)
      IF (I-1) 253,253,254
  253 PRINT 1220,SIG(I),BB,CC,EE,DD,FF
      GO TO 255
  254 PRINT 1230,SIG(I),AA,BB,CC,EE,DD,FF
  255 CONTINUE
  260 CONTINUE
      GO TO 280
  270 PRINT 1240
  280 READ 1000,ICROPCHG                  $ IF (ICROPCHG) 300,300,290
  290 GO TO (40,10),ICROPCHG
  300 END
      SUBROUTINE DATAFAC
      COMMON/NUMBERS/NBS,NPS,NBF,NPF,M,NP,NSTAGE,INDEXQ,NJ,NDATA,TFAC,
     *              DELTAT
      COMMON/CHANNELS/ICHUSE(7),IANUSE(7),ISAVE(7)
      COMMON/XSUMS/XX(31,7),XI(31,7),XK(31,7),XS(1000,7),DATA(62,7),
     *             XT(31,7),XJ(31,7),TJ(31,7),XTBAR(7),S(7)
      DO 20 J=1,7
      IF (ICHUSE(J)) 20,20,10
   10 XTBAR(J)=(XT(J)-XJ(J)*TJ(J)/NP)/NP
   20 CONTINUE
      END
      SUBROUTINE DATASET(I,IPS,JP,T)
      COMMON/NUMBERS/NBS,NPS,NBF,NPF,M,NP,NSTAGE,INDEXQ,NJ,NDATA,TFAC,
     *              DELTAT
      COMMON/CHANNELS/ICHUSE(7),IANUSE(7),ISAVE(7)
      COMMON/XSUMS/XX(31,7),XI(31,7),XK(31,7),XS(1000,7),DATA(62,7),
     *             XT(31,7),XJ(31,7),TJ(31,7),XTBAR(7),S(7)
      COMMON/ANEMFACS/U(255,7),ALPHA(7),BETA(7),A(7),B(7),C(7),D(7),
     *               E(7),F(7),G(7),H(7)
      COMMON/EXTRAS/VV(7),VEL(7),VELS(7),NSTAGECO
      COMMON/I/NUMPER,NUMBLOCK,NUMPNTS,IFLAG,ICHANNEL(1680),IDATA(1680)
      IF (NSTAGE-1) 2,2,1
    1 NPHASE=(M/2)**(NSTAGE-1)
```

```
    2 DO 50 J=1,7
      IPS=IPS+1                         $ IF (ICHUSE(J)) 50,50,10
   10 K=128+IDATA(IPS)                  $ L=128+ISAVE(J)
      IF (NSTAGE-1) 13,13,11
   11 VV(J)=VV(J)+U(K,J)                $ IF (JP-NPHASE) 14,12,12
   12 VEL(J)=VEL(J)+VV(J)/NPHASE
      VELS(J)=VELS(J)+(VV(J)/NPHASE)**2
      VV(J)=0.0                         $ GO TO 14
   13 VEL(J)=VEL(J)+U(K,J)              $ VELS(J)=VELS(J)+U(K,J)**2
   14 DATA(I,J)=U(K,J)-TFAC*U(L,J)      $ IF (NSTAGE-1) 20,20,30
   20 XT(J)=XT(J)+DATA(I,J)*T           $ XJ(J)=XJ(J)+DATA(I,J)
      TJ(J)=TJ(J)+T                     $ GO TO 40
   30 S(J)=S(J)+DATA(I,J)
   40 ISAVE(J)=IDATA(IPS)
   50 CONTINUE
      END
      SUBROUTINE DATASUM(ILOOP,KLOOP,LCHECK)
      COMMON/NUMBERS/NBS,NPS,NBF,NPF,M,NP,NSTAGE,INDEXQ,NJ,NDATA,TFAC,
     *                 DELTAT
      COMMON/CHANNELS/ICHUSE(7),IANUSE(7),ISAVE(7)
      COMMON/XSUMS/XX(31,7),XI(31,7),XK(31,7),XS(1000,7),DATA(62,7),
     *               XT(31,7),XJ(31,7),TJ(31,7),XTBAR(7),S(7)
      DO 100 J=1,7
      IF (ICHUSE(J)) 100,100,10
   10 IF (NSTAGE-1) 40,40,20
   20 DO 30 N=1,KLOOP
      II=(M/2)**(NSTAGE-1)              $ AJ=0.5*(II-1)
      T=(II*N-AJ)*DELTAT                $ XT(J)=XT(J)+XS(N,J)*T
      XJ(J)=XJ(J)+XS(N,J)               $ TJ(J)=TJ(J)+T
   30 CONTINUE
   40 DO 90 I=1,ILOOP
      DO 80 K=1,KLOOP
      L=K+I-1                           $ IF (NSTAGE-1) 50,50,60
   50 XS(K,J)=DATA(K,J)                 $ XS(L,J)=DATA(L,J)
   60 IF (L-LCHECK) 70,70,90
   70 XX(I,J)=XX(I,J)+XS(K,J)*XS(L,J)
      XI(I,J)=XI(I,J)+XS(K,J)           $ XK(I,J)=XK(I,J)+XS(L,J)
   80 CONTINUE
   90 CONTINUE
  100 CONTINUE
      END
      SUBROUTINE ENDPOINT
      COMMON/NUMBERS/NBS,NPS,NBF,NPF,M,NP,NSTAGE,INDEXQ,NJ,NDATA,TFAC,
     *                 DELTAT
      COMMON/EXTRAS/VV(7),VEL(7),VELS(7),NSTAGECO
      NP=(NBF-NBS+1)*1680-(NPS-1)-(1680-NPF)
      IF (NSTAGECO-1) 1,1,2
    1 NSET=NP/(7*M)                     $ NTEMP=NSET*7*M
      GO TO 3
    2 II=(M/2)**(NSTAGECO-1)            $ NSET=NP/(7*II)
      NTEMP=NSET*7*II
    3 NREMOVE=NP-NTEMP                  $ IF (NREMOVE-NPF) 20,10,10
   10 NBF=NBF-1
   20 NP=NTEMP
      NPF=NP-(NBF-NBS+1)*1680+(NPS-1)+1680
      NP=NP/7
      END
      SUBROUTINE FANDN
      TYPE REAL LH,NFN,NFFN,NFNR,NFFNR,NPFN,NPFFN
      COMMON/NUMBERS/NBS,NPS,NBF,NPF,M,NP,NSTAGE,INDEXQ,NJ,NDATA,TFAC,
```

```
     *                   DELTAT
      COMMON/VALUES/QK(31),QKK(31),LH(31),UH(31),FNQ(31),FN(31),FFN(31),
     *               NFN(31),NFFN(31),NFNR(31),NFFNR(31),NPFN(31),
     *               NPFFN(31),VH(31),FREQ(31),SIG(31),SUML
      NK=M+1                                   $ PI=3.1415927
      IF (NSTAGE-1) 10,10,20
   10 DT=DELTAT                                $ TAU=NP*DELTAT
      GO TO 30
   20 II=(M/2)**(NSTAGE-1)                     $ DT=II*DELTAT
      TAU=II*NP*DELTAT
   30 DO 160 I=1,NK
      K=I-1                                    $ FREQ(I)=K/(2.0*M*DT)
      SIG(I)=K*DT
   60 DN=1.0/(2.0*M*DT)
   70 FNQ(I)=UH(I)/DN                          $ GO TO (80,90),INDEXQ
   80 FN(I)=FNQ(I)/QK(I)                       $ GO TO 100
   90 FN(I)=FNQ(I)/QKK(I)
  100 A=PI*FREQ(I)*DT                          $ B=PI*FREQ(I)*TAU
      C=(SINF(A)/A)**2                         $ D=(SINF(B)/B)**2
      FFN(I)=FN(I)/(C-D)                       $ NFN(I)=FREQ(I)*FN(I)
      NFFN(I)=FREQ(I)*FFN(I)                   $ A=CUBERTF(FREQ(I))**5
      NPFN(I)=A*FN(I)                          $ NPFFN(I)=A*FFN(I)
      IF (I-1) 110,110,120
  110 FSAVE=NFN(I)                             $ FFSAVE=NFFN(I)
      GO TO 160
  120 IF (NFN(I)-FSAVE) 140,140,130
  130 FSAVE=NFN(I)
  140 IF (NFFN(I)-FFSAVE) 160,160,150
  150 FFSAVE=NFFN(I)
  160 CONTINUE
      DO 170 I=1,NK
      NFNR(I)=NFN(I)/FSAVE                     $ NFFNR(I)=NFFN(I)/FFSAVE
  170 CONTINUE
      END
      SUBROUTINE INITIAL
      COMMON/NUMBERS/NBS,NPS,NBF,NPF,M,NP,NSTAGE,INDEXQ,NJ,NDATA,TFAC,
     *                   DELTAT
      COMMON/CHANNELS/ICHUSE(7),IANUSE(7),ISAVE(7)
      COMMON/XSUMS/XX(31,7),XI(31,7),XK(31,7),XS(1000,7),DATA(62,7),
     *                XT(31,7),XJ(31,7),TJ(31,7),XTBAR(7),S(7)
      COMMON/EXTRAS/VV(7),VEL(7),VELS(7),NSTAGECO
      NK=M+1
      DO 50 J=1,7
      IF (ICHUSE(J)) 50,50,10
   10 XT(J)=0.0                                $ XJ(J)=0.0
      TJ(J)=0.0                                $ VEL(J)=0.0
      VELS(J)=0.0
      IF (NSTAGE-1) 30,30,20
   20 S(J)=0.0                                 $ VV(J)=0.0
   30 DO 40 I=1,NK
      XX(I,J)=0.0                              $ XI(I,J)=0.0
      XK(I,J)=0.0
   40 CONTINUE
   50 CONTINUE
      END
      SUBROUTINE LSUMH
      TYPE REAL LH,NFN,NFFN,NFNR,NFFNR,NPFN,NPFFN
      COMMON/NUMBERS/NBS,NPS,NBF,NPF,M,NP,NSTAGE,INDEXQ,NJ,NDATA,TFAC,
     *                   DELTAT
      COMMON/VALUES/QK(31),QKK(31),LH(31),UH(31),FNQ(31),FN(31),FFN(31),
```

```
     '                   NFN(31),NFFN(31),NFNR(31),NFFNR(31),NPFN(31),
     *                   NPFFN(31),VH(31),FREO(31),SIG(31),SUML
      DIMENSION Q(31)
      NK=M+1                                $ NM=NK-1
      PI=3.1415927                          $ SUML=0.0
      DO 30 I=1,NK
      GO TO (10,20),INDEXO
   10 O(1)=OK(I)                            $ GO TO 30
   20 O(I)=OKK(I)
   30 CONTINUE
      DO 110 I=1,NK
      IF (I-1) 50,50,40
   40 IF (I-NK) 70,90,90
   50 LH(I)=(O(1)+O(NK))/(2.0*M)            $ SUM=0.0
      DO 60 J=2,NM
      SUM=SUM+O(J)
   60 CONTINUE
      LH(I)=LH(I)+SUM/M                     $ SUML=SUML+LH(I)
      GO TO 110
   70 LH(I)=(O(1)+O(NK)*COSF((I-1)*PI))/M
      SUM=0.0
      DO 80 J=2,NM
      ANG=(I-1)*(J-1)*PI/M                  $ SUM=SUM+O(J1*COSF(ANG)
   80 CONTINUE
      LH(I)=LH(I)+2.0*SUM/M                 $ SUML=SUML+LH(I)
      GO TO 110
   90 LH(I)=(O()+(-1)**M*O(NK))/(2.0*M)
      SUM=0.0
      DO 100 J=2,NM
      SUM=SUM+(-))**(J-1)*O(J)
  100 CONTINUE
      LH(I)=LH(1)+SUM/M                     $ SUML=SUML+LH(I1
  110 CONTINUE
      END
      SUBROUTINE PHASESUM
      COMMON/NUMBERS/NBS,NPS,NBF,NPF,M,NP,NSTAGE,INDEXO,NJ,NDATA,TFAC,
     *                DELTAT
      COMMON/CHANNELS/ICHUSE(7),IANUSE(7),ISAVE(7)
      COMMON/XSUMS/XX(3),7),XI(31,7),XK(31,7),XS(1000,7),DATA(62,7),
     *              XT(3),7),XJ(31,7),TJ(31,7),XTBAR(7),S(7)
      COMMON/1/NUMPER,NUMBLOCK,NUMPNTS,IFLAG,ICHANNEL(1680),IDATA(1680)
      NK=M+1                                $ IF (NSTAGE-1) 10,10,20
   10 NPHASE=M                              $ GO TO 30
   20 NPHASE=(M/2)**(NSTAGE-1)
   30 CALL INITIAL                          $ IF (NUMBLOCK-NBS) 40,60,60
   40 NTIME=NBS-NUMBLOCK
      DO 50 I=),NTIME
      CALL CRACK
   50 CONTINUE
   60 IPS=NPS-1                             $ IF (NUMBLOCK-NBF) 70,80,80
   70 IPF=1680                              $ GO TO 90
   80 IPF=NPF
   90 NS=1                                  $ NF=2*NK
      JP=0                                  $ IF (NSTAGE-1) 110,110,100
  100 NP=0
  110 DO 260 I=NS,NF
      JP=JP+1                               $ IF (NSTAGE-1) 120,120,130
  120 NSTORE=1                              $ T=JP*DELTAT
      GO TO 140
  130 T=0.0
```

```
140 CALL DATASET(I,IPS,JP,T)            $ IF (NSTAGE-1) 190,190,150
150 IF (JP-NPHASE) 190,160,160
160 NP=NP+1                             $ JP=0
    DO 180 L=1,7
    IF (ICHUSE(L)) 180,180,170
170 XS(NP,L)=S(L)/NPHASE                $ S(L)=0.0
180 CONTINUE
190 IF (IPS-IPF) 260,200,200
200 IF (NUMBLOCK-NBF) 230,210,210
210 IF (NSTAGE-1) 220,220,290
220 NSTOP=2                             $ GO TO 280
230 CALL CRACK                          $ IPS=0
    IF (NUMBLOCK-NBF) 240,250,250
240 IPF=1680                            $ GO TO 260
250 IPF=NPF
260 CONTINUE
    IF (NSTAGE-1) 270,270,110
270 NSTOP=1
280 ILOOP=NK                            $ KLOOP=NK
    LCHECK=NSTORE                       $ GO TO 300
290 ILOOP=NK                            $ KLOOP=NP
    LCHFCK=NP
300 CALL DATASUM(ILOOP,KLOOP,LCHECK)
    IF (NSTAGE-1) 310,310,390
310 GO TO (320,320,380),NSTOP
320 K=NSTORF-NK
    DO 350 J=1,7
    IF (ICHUSF(J)) 350,350,330
330 DO 340 I=1,K
    L=NK+I                              $ DATA(I,J)=DATA(L,J)
340 CONTINUE
350 CONTINUF
    GO TO (360,370,380),NSTOP
360 NS=NK+1                             $ NF=2*NK
    GO TO 110
370 NSTOP=3                             $ NSTORF=K
    GO TO 280
380 NP=JP
390 IF (NP-NK) 400,410,410
400 NOATA=0                             $ GO TO 420
410 NDATA=1                             $ CALL DATAFAC
420 END
    SUBROUTINE QSUBKS
    TYPE REAL LH,NFN,NFFN,NFNR,NFFNR,NPFN,NPFFN
    COMMON/NUMBERS/NBS,NPS,NBF,NPF,M,NP,NSTAGE,INDEXQ,NJ,NDATA,TFAC,
   *                 DELTAT
    COMMON/XSUMS/XX(31,7),XI(31,7),XK(31,7),XS(1000,7),DATA(62,7),
   *              XT(31,7),XJ(31,7),TJ(31,7),XTBAR(7),S(7)
    COMMON/VALUES/QK(31),QKK(31),LH(31),UH(31),FNQ(31),FN(31),FFN(31),
   *               NFN(31),NFFN(31),NFNR(31),NFFNR(31),NPFN(31),
   *               NPFFN(31),VH(31),FREQ(31),SIG(31),SUML
    NK=M+1                              $ J=NJ
    DO 10 I=1,NK
    K=I-1
    QK(I)=(XX(I,J)-XI(I,J)*XK(I,J)/(NP-K))/(NP-K)
 10 CONTINUF
    IF (NSTAGF-1) 20,20,30
 20 T=NP*DELTAT                         $ GO TO 40
 30 T=(M/2)**(NSTAGE-1)*NP*DELTAT
 40 DO 50 I=1,NK
```

```
      QKK(I)=QK(I)-12.0*XTBAR(J)**2/T**2
   50 CONTINUE
      END
      SUBROUTINE USUBH
      TYPE REAL LH,NFN,NFFN,NFNR,NFFNR,NPFN,NPFFN
      COMMON/NUMBERS/NBS,NPS,NBF,NPF,M,NP,NSTAGE,INDEXO,NJ,NDATA,TFAC,
     *               DELTAT
      COMMON/VALUES/QK(31),QKK(31),LH(31),UH(31),FNO(31),FN(31),FFN(31),
     *              NFN(31),NFFN(31),NFNR(31),NFFNR(31),NPFN(31),
     *              NPFFN(31),VH(31),FREQ(31),SIG(31),SUML
      NK=M+1                               $ PI=3.1415927
      IF (TFAC-0.0000001) 10,10,70
   10 DO 60 I=1,NK
      IF (I-1) 30,30,20
   20 IF (I-NK) 40,50,50
   30 UH(I)=0.54*LH(I)+0.46*LH(I+1)        $ GO TO 60
   40 UH(I)=0.54*LH(I)+0.23*(LH(I-1)+LH(I+1))
      GO TO 60
   50 UH(I)=0.54*LH(I)+0.46*LH(I-1)
   60 CONTINUE
      GO TO 90
   70 DO 80 I=1,NK
      J=I-1                                $ ANG=PI*J/M
      TEMP=1.0+TFAC**2-2.0*TFAC*COSF(ANG)
      UH(I)=VH(I)/TEMP
   80 CONTINUE
   90 END
      SUBROUTINE VELCOREL
      COMMON/CHANNELS/ICHUSE(7),IANUSE(7),ISAVE(7)
      COMMON/ANEMFACS/U(255,7),ALPHA(7),BETA(7),A(7),B(7),C(7),D(7),
     *                E(7),F(7),G(7),H(7)
      DO 80 J=1,7
      IF (ICHUSE(J)) 80,80,10
   10 NTIME=1                              $ NS=1
      NF=128                               $ K=IANUSE(J)
   20 DO 60 L=NS,NF
      GO TO (30,40),NTIME
   30 N=L-128                              $ I=L
      GO TO 50
   40 N=L                                  $ I=128+L
   50 X=ALPHA(K)+BETA(K)*N
      AA=1.0                               $ BB=X
      CC=X*X                               $ DD=X*X*X
      EE=1.0/X                             $ FF=1.0/CC
      GG=SQRTF(X)                          $ HH=1.0/DD
      AA=AA*A(K)                           $ BB=BB*B(K)
      CC=CC*C(K)                           $ DD=DD*D(K)
      EE=EE*E(K)                           $ FF=FF*F(K)
      GG=GG*G(K)                           $ HH=HH*H(K)
      U(I,J)=AA+BB+CC+DD+EE+FF+GG+HH
   60 CONTINUE
      GO TO (70,80),NTIME
   70 NS=1                                 $ NF=127
      NTIME=2                              $ GO TO 20
   80 CONTINUE
      END
      SUBROUTINE VSUBH
      TYPE REAL LH,NFN,NFFN,NFNR,NFFNR,NPFN,NPFFN
      COMMON/NUMBERS/NBS,NPS,NBF,NPF,M,NP,NSTAGE,INDEXO,NJ,NDATA,TFAC,
     *               DELTAT
```

```
      COMMON/VALUES/QK(31),QKK(31),LH(31),UH(31),FNQ(31),FN(31),FFN(31),
     *               NFN(31),NFFN(31),NFNR(31),NFFNR(31),NPFN(31),
     *               NPFFN(31),VH(31),FREQ(31),SIG(31),SUML
      NK=M+1
      DO 50 I=1,NK
      IF (I-1) 20,20,10
   10 IF (I-NK) 30,40,40
   20 VH(I)=0.54*LH(I)+0.46*LH(I+1)     $ GO TO 50
   30 VH(I)=0.54*LH(I)+0.23*(LH(I-1)+LH(I+1))
      GO TO 50
   40 VH(I)=0.54*LH(I)+0.46*LH(I-1)
   50 CONTINUE
      END
      SUBROUTINE YSETUP
      COMMON/NUMBERS/NBS,NPS,NBF,NPF,M,NP,NSTAGE,INDEXQ,NJ,NDATA,TFAC,
     *                 DELTAT
      COMMON/CHANNELS/ICHUSE(7),IANUSE(7),ISAVE(7)
      COMMON/1/NUMPER,NUMBLOCK,NUMPNTS,IFLAG,ICHANNEL(1680),IDATA(1680)
      IF (NPS-7) 10,10,20
   10 NBTEMP=NBS-1                        $ K=1673
      GO TO 30
   20 NBTEMP=NBS                          $ K=NPS-8
   30 IF (NUMBLOCK-NBTEMP) 40,60,60
   40 NTIME=NBTEMP-NUMBLOCK
      DO 50 I=1,NTIME
      CALL CRACK
   50 CONTINUE
   60 DO 70 I=1,7
      J=K+I                               $ ISAVE(I)=IDATA(J)
   70 CONTINUE
      END
      SUBROUTINE CRACK
      COMMON/1/NUMPER,NUMBLOCK,NUMPNTS,IFLAG,ICHAN(1680),IDATA(1680)
      COMMON/2/BLOCK(421),JLEN
      IFLAG = 00
1     IF(UNIT,1)1,2,2,2
2     BUFFER IN(1,1)(BLOCK,BLOCK(421))
3     IF(UNIT,1)3,100,5,7
5     IFLAG = 1
      NUMPNTS = 0
      RETURN
7     NREAD = 0
8     BACKSPACE 1
9     IF(UNIT,1)9,10,10,10
10    BUFFERIN(1,1)(BLOCK,BLOCK(421))
11    IF(UNIT,1)11,100,5,12
12    NREAD = NREAD +1
      IF(NREAD .GE. 3) 14,8
14    IFLAG = 2
      JLEN = LENGTHF(1)
      IF(JLEN .EQ. 421) 105,15
15    IF(JLEN .EQ. 1       ) 102,103
100   JLEN = LENGTHF(1)
      IF(JLEN .EQ. 421)105,101
101   IF(JLEN .EQ. 1) 102,103
102   NUMPNTS = 0
      CALL CRACK2
      RETURN
103   IFLAG =  3
105   CONTINUE
```

```
      106   CALL  CRACK3
            RETURN
            END
                  IDENT       CRACK2
                  ENTRY       CRACK2
                  ENTRY       CRACK3
      1           BLOCK
                  COMMON      NUMPER
                  COMMON      NUMBLOCK
                  COMMON      NUMPT
                  COMMON      IFL
                  COMMON      A(1680)
                  COMMON      B(1680)
      2           BLOCK
                  COMMON      BASE
                  COMMON      C(420)
                  COMMON      N
      CRACK4      SLJ
                  LDQ         BASE
                  ENA
                  LLS         12
                  STA         NUMPER
                  ENA
                  LLS         12
                  STA         NUMBLOCK
                  ENA
                  LLS         12
                  STA         NUMPT
                  SLJ         CRACK4
      CRACK2      SLJ
                  RTJ         CRACK4
                  ENA
                  STA         NUMPT
                  SLJ         CRACK2
      CRACK3      SLJ
                  RTJ         CRACK4
                  RTJ         GO
      +           SLJ         CRACK3
      GO          SLJ
                  NOP
                  SIU     1   SAVE
                  SIL     2   SAVE
                  SIU     3   XR
                  LIL     1   N
                  INI     1   -2
                  ENI     2
                  ENI     3
      GA          LDQ     2   C
                  ENA
                  LLS         8
                  STA     3   B
                  ENA
                  LLS         4
                  STA     3   A
                  INI     3   1
                  ENA
                  LLS         8
                  STA     3   B
                  ENA
                  LLS         4
```

```
         STA    3  A
         INI    3  1
         ENA
         LLS       8
         STA    3  B
         ENA
         LLS       4
         STA    3  A
         INI    3  1
         ENA
         LLS       8
         STA    3  B
         ENA
         LLS       4
         STA    3  A
         INI    3  1
         INI    2  1
         IJP    1  GA
         INI    3  -1
GB       LDA    3  B
         SCL       MASKZ
         AJP    Z  GC
         LDA    3  B
         SST       MASK2
         STA    3  B
GC       IJP    3  GB
SAVE     ENI    1
         ENI    2
XR       ENI    3
         SLJ       GO
MASKZ    OCT       177
MASK2    OCT       7777777777777600
         END
         END       PSPECTRA
         FINIS
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13. ABSTRACT

Mean horizontal windspeed profiles within and above a plantation of Japanese larch were obtained. A log-profile analysis of above-vegetation windspeeds yielded a wide range of values for the roughness length parameter (z_o) and the zero plane displacement height (D), with these two parameters being highly correlated with each other. The computed Eulerian space scale of turbulence within the vegetation showed deeper penetration of large eddies after needle fall and during high winds. Power spectra showed that at the base of the plantation most of the variation in windspeed was associated with gusts of about 100 meters wavelength. Power spectra at the most dense portion of the plantation canopy showed considerable modification due to the tree spacing.

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14. KEY WORDS	LINK A ROLE	LINK A WT	LINK B ROLE	LINK B WT	LINK C ROLE	LINK C WT
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Power spectra of turbulence						
Windspeed profiles						
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